A STUDY OF NOTCH-SENSITIVITY IN FATIGUE OF METALS

BY

CHIA-SHIANG YEN

B.S., National Central University, China, 1939
M.S., University of Illinois, 1946

AN ABSTRACT OF A THESIS

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Introduction

Notch-sensitivity in fatigue of metals has been an important subject in engineering research, and interpretations of fatigue test data for notched specimens have been made by numerous investigators, but the results thus far reported are still far from being satisfactory. It was the purpose of this thesis: (1) to review and to appraise various previous interpretations of data from fatigue tests of notched specimens, (2) to study the stress distribution in the notched section of a fatigue specimen and the structural action as affected by plastic deformation and work-hardening in fatigue test, and (3) to attempt to formulate an hypothesis of fundamental nature which would explain the fatigue phenomena for notched specimens.

Review Of Previous Investigations

Many previous interpretations of fatigue test data for notched specimens were reviewed and appraised. Most of these previous analyses were primarily qualitative and based on approximate concepts of basic material behavior, such as plasticity, ductility, damping capacity, cohesive strength, work-hardening capacity, elementary structural unit, statistical theories of fatigue, or homogeneity of material. Interpretations based on static tensile strength or impact strength were only indirect and accidental, and did not lead to an accurate and functional correlation. Some interpretations were based on the stress conditions as affected by the geometry of the notch, such as, state of stress, shear energy theory, stress gradient, and extent of stress concentration. Other quantitative approaches, such as the theories of change of notch radius, and of failure below surface, were made from speculative thinking without evidence in the light of recent

fatigue tests or theories. However, some of these analyses agreed well with a limited amount of test data, and each approach seems to express a partial truth regarding the behavior of a notched specimen.

Structural Action In The Notched Specimen

The stress distribution in the notched section and the mechanical hysteresis loop for a fatigue specimen were studied. For completely-reversed loading at the stress level of endurance limit, the stress on the weaker crystals in a specimen may decrease during the initial cycles of repeated loading due to plastic deformation, but eventually the yield strength of the weaker crystals will increase to the level required to resist the imposed stress without further plastic deformation due to work-hardening. The final stress distribution then would be the same as that computed by elastic theory, and the actual maximum stress existing at the root of the notch would be equal to the theoretical (elastic) maximum stress.

Development And Application Of The Hypothesis

In the light of recent fatigue theories, it was assumed that the criterion for fatigue strength for any kind of specimen was based upon two material properties: (1) an "intrinsic endurance limit"; and (2) a critical amount of fatigue damage (closely related to the work-hardening capacity). After several trials, an expression for the critical amount of fatigue damage was formulated and equations were derived to express the property of notch-sensitivity and the fatigue limit for any rotating beam specimens, large or small, notched or unnotched. The resulting equations apparently agreed well with the general conclusions drawn from the observations of the phenomena of notch-sensitivity; other things being equal, the notch-sensitivity increased with increase of diameter or of material homogeneity of specimen, and decreased with increase of the relative stress gradient or the work-hardening capacity.

Empirical methods were proposed to evaluate the material

constants in the equations so that one may use the equations to predict the endurance limit for any rotating beam specimen. The available test results for several sizes of notched and unnotched specimens of six different steels gave endurance limits which deviated from those computed from the equations by amounts ranging from + 10.1 per cent to — 7.7 per cent.

VITA

Chia-Shiang Yen was born in Kiangsu, China, December 10, 1917. Upon graduation from the Provincial Nanking Middle School he entered the National Central University, Nanking, China, and received the degree of Bachelor of Science in Civil Engineering in July, 1939.

The following September he started to work in the Material Testing Laboratory of the above named University as a Research Assistant and Instructor teaching the courses of Engineering Materials and Material Testing. In February, 1945, he entered the Graduate School of the University of Illinois and received the Master of Science degree in Civil Engineering in June, 1946. Since that time he has continued his graduate work in the Department of Theoretical and Applied Mechanics.

He has been appointed Special Research Graduate Assistant since October, 1946, and worked on the cooperative research project "An Investigation of the Behavior of Materials under Repeated Stress," being conducted for the Office of Naval Research, U.S. Navy. Since then he has been a co-author of the following two reports:

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